ASTRONAUT HEALTH

The Effect of Unloading on the Metatarsal Bone of the Rat

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The bones of the feet are likely to lose mineral during spaceflight because they are not functioning to support body weight in space. Although loss of bone from the heel bone (calcaneus) during spaceflight is well documented, loss of mineral from other bones in the feet of astronauts has not been quantified. A possibly vulnerable candidate is the metatarsal, which, as a weight-bearing bone in runners, is vulnerable to stress fractures.

To explore the potential for bones of the feet to lose mineral, a model of a metatarsal in mature rats exposed to a spaceflight was used. The experiment was designed to analyze the third metatarsal, depicted in the first figure, at the start and after one, four, and eight weeks of unloading of the hindlimbs by tail suspension. In this model, the hindpaws are raised about one centimeter off the floor of the cage. At the end of the experiment, the animals were weighed. The third metatarsal from the right foot of each group of rats was removed, dried, and ashed at 600 degrees Centigrade (°C) to determine the mineral content. The soleus muscle, which regularly atrophies in this model, was also removed and weighed.

Body weights decreased about 10% during the first week of the experiment and remained stable thereafter. The body weights in the suspended animals remained lower than in the controls. The soleus muscle, illustrated in the first figure, gradually decreased after one week of unloading to 72% of control, and after 8 weeks of unloading to 38% of control, as shown in the second figure (panel A). The third metatarsal weights showed no differences in any group, as illustrated in panel B of the second figure.

The finding of normal mineralization in the third metatarsal in spite of 8 weeks of unweighting, sufficient to cause atrophy in the soleus muscle, was unexpected. Chemical analysis of the collagen from the diaphysis of the tibiae from this study by others shows changes consistent with a mineralization defect in that bone. Previous researchers have measured the amount of load imposed on the hindlimbs during normal walking in the rat and found it to be 60% of the body weight. How the metatarsal functions in supporting this weight is not precisely known. It is known that bone turnover in mature rats is exceedingly slow, especially when compared to human bone. Eight weeks of unloading may not be sufficient time to show the mineral loss in this species. Additionally, a small decrease in the bone mineral content of a small bone may not be detectable by these methods, which have a limit of detection in the order of 50 milligrams of mineral. Whatever the explanation, the observation illustrates both bone and species specificity of detectable osteopenia following skeletal unloading.

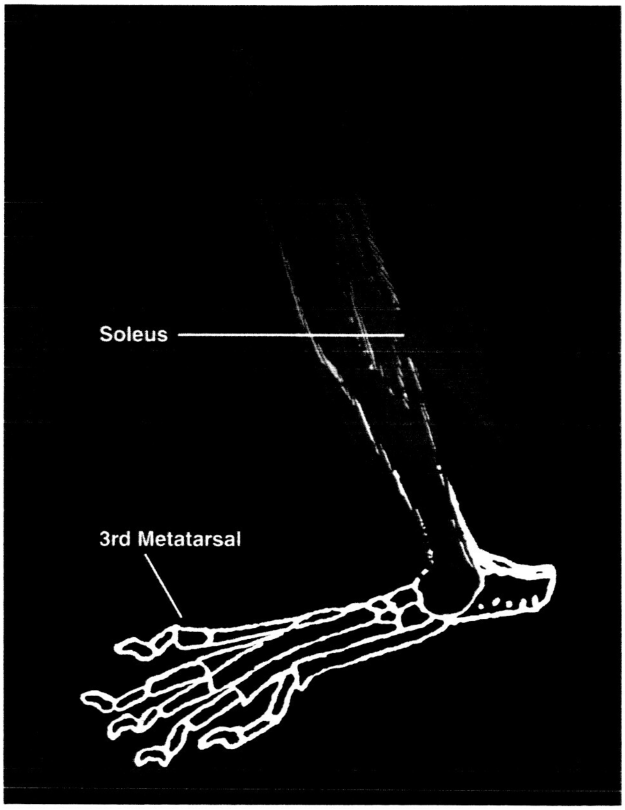

Fig. 1. The leg of the rat showing the central third metatarsal bone and the soleus muscle.

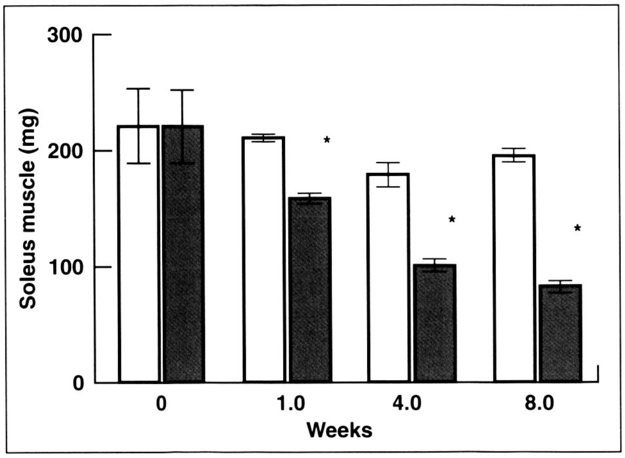

Fig. 2(a). Soleus muscle weights in 400-gram male rats exposed to 8 weeks of hindlimb unloading (shaded) compared to ambulatory controls. Asterisks indicate differences, significance at $p < 0.05$.

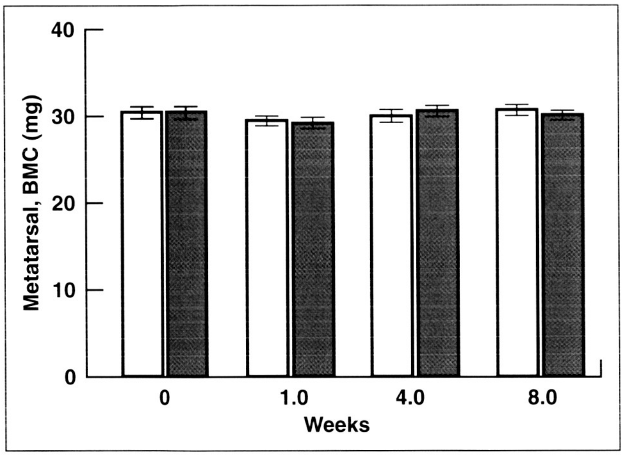

Fig. 2(b). Bone mineral content in the third metatarsal of 400-gram male rats exposed to 8 weeks of hindlimb unloading (shaded) compared to ambulatory controls. None of the apparent differences are significant at $p < 0.05$.

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Inducing Presyncope in Men: A Comparison of Two Stimuli

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NASA has identified cardiovascular deconditioning as a serious biomedical problem associated with long-duration exposure to microgravity in space. High priority has been given to the development of countermeasures for this disorder and the resulting orthostatic intolerance (sudden drop in blood pressure while standing) experienced by crewmembers upon their return to the norm of Earth. This in turn leads to presyncopal symptoms, that is, feeling lightheaded or dizzy just prior to fainting.

The primary purpose of the present study was to directly compare two tests of orthostatic tolerance in normal adult men. The first was a supine lower-body negative pressure (LBNP) test and the second was a combined test of head-up tilt (HUT) and LBNP. In order to test countermeasures for postflight orthostatic intolerance, investigators needed to understand the nature of physiological responses to a gravitational stress. This study would determine which of these types of tolerance tests is best suited for evaluating treatments or countermeasures that will be used to help future astronauts adapt more readily to microgravity as well as to facilitate readaptation to Earth.

Eight men, average age 37.5, were tested. Several physiological responses were measured using the Autogenic-Feedback System-2 (AFS-2), which is designed for monitoring crewmembers in space. Each subject received one supine LBNP test and one HUT + LBNP test, administered at one-week intervals.

The LBNP device is a clear plastic tube (mounted on a tilt-table), which covered the subject's feet and legs while he was lying flat on his back (supine), and was sealed at the waist with a soft rubber strip. Ten minutes of resting baseline data were collected, then the air was removed from the LBNP tube with a vacuum system. Removing the air from the tube had the effect of pulling blood from the subject's upper body down to the legs, resulting in lowered blood pressure as gradually more air was removed at increments of 10 mm Hg (millimeters of mercury) every three minutes. The maximum negative pressure was –100 mm Hg. The HUT + LBNP was essentially